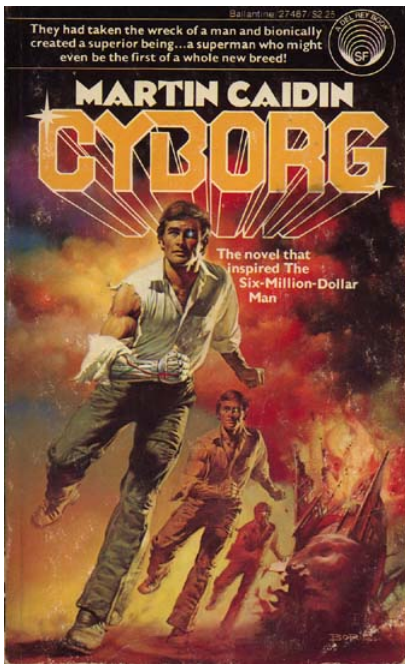


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A Cyborg Space Race



Cyborg, a science fiction novel by Martin Caidin. Image Credit: *Ballantine Books*.



Astronauts need to wear protective gear to venture out into space. Not only do their lives depend on the spacesuit working properly, but they must limit their time in space because the suits don't provide much radiation shielding. Image credit: *NASA*



Kevin Warwick with his second cyborg implant. This implant, connected to the median nerve in his arm, allowed him to send and receive signals by computer.

Image credit: *University of Reading*



Artificial kidneys are not yet small enough to be implantable. Victor Gura, who is developing an artificial kidney at UCLA's School of Medicine, models the device.

Image credit: *UCLA*

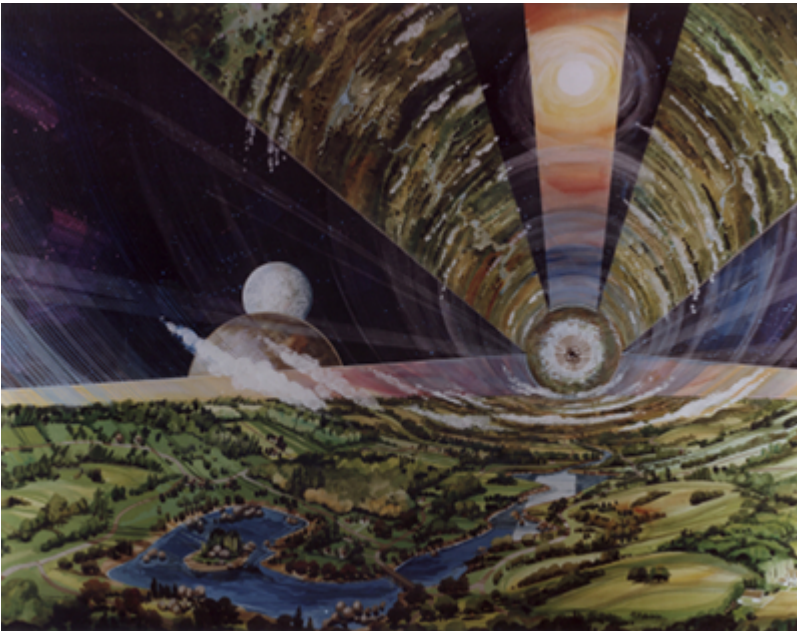


Humans on Mars will need to wear spacesuits when exploring the planet. Not only does Mars lack oxygen, but due to the thin atmosphere, astronauts would be exposed to high levels of UV radiation. Martian and lunar habitats probably will be at least partly buried under the soil in order to reduce radiation exposure. Image Credit: *Mars Institute (marsonearth.org)*



Brain implants are being used for medical conditions like Parkinson's disease and depression. Transhumanists think one day brain implants could be used for much more.

Image credit: *St. Jude Medical*



Artistic representation of a human space colony. These habitats would recreate aspects of Earth's environment, but future colonists may feel like they're living in a fishbowl.

Image credit: *NASA Ames Research Center*

Electrodes and a control chip are inserted into a moth during its pupal stage. When the moth emerges the electrodes stimulate its muscles to control its flight.

Image credit: *Alper Bozkurt, Boyce Thompson Institute*

Cyborgs – human beings merged with machines -- are a staple of science fiction. *Star Wars's* Darth Vader, *Star Trek's* Borg, and the *Cybermen* of Dr. Who are variations on this theme – and it's no coincidence they're all "bad guys." Cyborgs symbolize one of our greatest fears: that over time, we will become so enmeshed in our technology that we lose our humanity.

The real-life application of cyborg science is far from horrifying. Medical technology has developed implantable heart pacemakers, insulin pumps, hearing aids, and even computer chips for the brain to treat depression and Parkinson's disease. In that sense, we are already on the path to becoming cyborgs.

Transhumanists believe that the development of such technology will lead one day to "Human version 2.0" – an upgrade of the human body that not only eliminates many of the problems that plague us, but improves upon the basic human design. For instance, some transhumanists envision a day when the human brain will be re-wired with computer chips, allowing us to think, learn and communicate with unprecedented speed and accuracy.

There's an ethical leap between using technology to help people overcome disabilities, and using it to "improve" healthy humans. The 1972 science fiction novel, *Cyborg* by Martin Caidin, which was turned into the popular TV show *The Six-Million-Dollar Man*, bridges the gap by creating a cyborg superman as a life-saving measure. The title character was a NASA test pilot who suffered traumatic injuries when his plane crashed. His legs, left arm, and an eye were replaced with bionic parts, giving him superior speed, strength and vision.

Martin Caidin's novel may have been inspired by discussions taking place within the space community around that time. NASA had considered the possibility of engineering humans, not to create super heroes, but to help us travel to the other planets and the stars beyond.

Building a Better Astronaut

Without a spacesuit, a person could only survive for about 90 seconds in the vacuum of space. Not only does space lack breathable oxygen, but the vacuum pressure would cause the blood in your veins to bubble and expand. Space is so cold – minus 270 C (minus 454 F) – you would be frozen solid in short order. Radiation is another mode of destruction – space contains high energy gamma and X-rays, as well as the lower energy but still harmful UV.

In 1960, Manfred Clynes and Nathan Kline published an essay in *Astronautics* titled "Cyborgs in Space." Comparing man in space to a fish out of water, they noted that even if you could bring everything you need on your space explorations, "the bubble all too easily bursts."

However, if the human body were altered to adapt to the conditions of space, astronauts would be free to explore the universe without limitation.

"Solving the many technical problems involved in manned space flight by adapting man to his environment, rather than vice versa, will not only mark a significant step forward in man's scientific progress, but may well provide a new and larger dimension for man's spirit as well," the authors write.

The Clynes & Kline paper coined the term "cyborg," and NASA followed up on their suggestions, commissioning a study on the topic. "The Cyborg Study: Engineering Man for Space" was released in 1963, and it reviewed the possibility of organ replacement, as well as how drugs and hibernation could be used to make space travel less stressful. The report concluded that replacing the heart, lungs and kidneys – the organs most stressed by space travel – was not feasible with the technology available at the time.

In considering how hibernation and drugs could be used to deal with physical and psychological stress, the study's scope included master control over an astronaut's brain and body. The current academic discussion of cyborg studies embraces an even broader view of "cyborg" to mean the general impact of technology on our lives.

"You could say that cyborgization started with furs and fire, and certainly with glasses and dentures," says James Hughes, medical ethicist at Trinity College in Hartford, Connecticut.

Hughes is the author of the book, *Citizen Cyborg: Why Democratic Societies Must Respond to the Redesigned Human of the Future*. Hughes says we should acknowledge that we are already living in the Age of the Cyborg. This process has been gradual but steady, and as medical technology advances, more people will opt for the advantages of the latest innovations -- so long as they're convinced the benefits outweigh the risks. Hughes points to LASIK eye surgery as one example.

"I continue to wear glasses, and one of the reasons is that I want to see more evidence that LASIK really works in ways it's supposed to," says Hughes. "I haven't been convinced yet. I think many people will have

that reaction to sticking hardware in their brain. Your laptop is obsolescent almost the day you buy it, so why would you want to stick something in your brain when you'd need surgery in order to replace it?"

Today a surgical brain implant such as the one to treat Parkinson's disease is a remedy of last resort. But if the technology was more benign, with an easier way for people to download the latest upgrade, such implants might become more common.

"You might imagine that you could swallow a nanotech pill, and nanobots would unfold in your gut and migrate their way past the blood-brain barrier and find where they're supposed to go," says Hughes. "You could theoretically give them instructions, and say, 'It's time for you guys to flush out because I want the next upgrade.' They all die and go out in your urine, and then you take another pill."

Kevin Warwick, of the Cybernetic Intelligence Research Group at the University of Reading in England, isn't waiting for the invention of medical nanobots. He had a computer device surgically implanted in his arm in two separate experiments.

As recounted in his book, *I, Cyborg*, the first experiment involved a radio frequency identification (RFID) chip enclosed in a glass tube. The tube was inserted under the skin in his arm, and the RFID chip communicated with a computer. In the second, more invasive experiment, spikes on a silicon microarray were pounded directly into the median nerve in his left arm. This 100 electrode array allowed his nervous system to receive signals from a computer. Warwick and his colleagues performed various experiments, including operating a wheelchair, sending signals over the Internet, and human-to-human communication (via a wire implanted in his wife's arm). Warwick's nerve implant was removed after several months, after the planned experiments were completed.

Warwick says that other than tingly feelings in his fingers due to nerve fiber regeneration, he didn't experience any unusual physical effects from the implant. Before the experiment, he had wondered if his brain would even respond to the electrical signals. If it did accept the signals, would it be able to translate them? Or would the unusual new data overwhelm his brain? Luckily his brain was able to make sense of the input, but when he talks about his experiment with neurosurgeons or other doctors, they often express concern.

"Various surgeons have said I could've had serious problems with putting electrical current into my nervous system that was going up to my brain," says Warwick. "Some of the signals were quite strong, because we were trying to force the brain to not ignore them. My brain could have decided to go on holiday, or I could have gone crazy. It's probably just as well I didn't know completely the things that could've gone wrong."

Despite such risks, Warwick sees huge potential in developing implantable computer chips. He's currently trying to improve the Parkinson's brain implant to better predict the onset of tremors. He also thinks computer chips could be used to bridge broken nerve fibers, bringing movement back to paralyzed body parts, but this concept remains purely speculative.

"For a serious break or lesion, how much you can bring that into play is a big question," says Warwick. "We can't see why people haven't tried [to use computer chips to stimulate damaged nerves] yet, because it seems an obvious thing to try."

A lot of cyborg technology remains either speculative or a long way from practical implementation. The development of artificial organs is not too far advanced from what was available when NASA commissioned its cyborg study. Although artificial hearts and lungs are now more compact and better at the jobs they were designed for, they are used mainly as temporary replacements to help patients survive until appropriate donor organs become available. Artificial kidneys – dialysis machines – have posed the greatest challenge, partly due to the need to filter large amounts of fluid. In the 60s, artificial kidneys were the size of a refrigerator. Today, the smallest devices are still not implantable, but a recent prototype can be worn as an

extremely bulky utility belt. Artificial bones, blood, skin, eyes, and even noses are now all being developed, and each could conceivably help man cope with the conditions of space. So long as the resulting entity still had a human brain, it could be considered a cyborg rather than an android (a robot that looks like a human).

However, NASA isn't devoting any thought these days on how to build a better astronaut. Their Human Research Program instead focuses on ways that drugs, exercise, better spacesuits and radiation shielding can mitigate the effects of the space environment on human health. There is more discussion in the space community on how to alter entire planets to suit humans – a process called “terraforming” – than there is on changing man to suit space.

One reason NASA has little interest in cyborgs may be due to their focus on bringing astronauts back home safely. Humans altered for life in space might not fare too well on Earth. Permanent adaptation is an issue for future Mars colonists as well, since over time the weaker gravity could result in thinner bones. While some have advocated “one-way trips,” with people living out the remainder of their lives on Mars, current NASA plans envision stays lasting only 500 days.

Warwick is disappointed by NASA's lack of research into the possibilities of a cyber-astronaut corps.

“They're taking the easier option as far as public opinion is concerned,” says Warwick. “It's certainly not the most exciting one as far as research is concerned, and hence [not the field] with the biggest potential. So it's a shame.”

But Hughes says that astronauts, along with all the other people on Earth, will inevitably end up with cyborg upgrades.

“I think that we're all going to be engineering ourselves for various things in this century,” says Hughes. “Certainly the rigors of space travel are going to require extensive bioengineering, unless we come up with some incredible material science. So I assume that, just like the kinds of things we'll all be doing on Earth, astronauts will avail themselves of those things.”

To Infinity and Beyond

Robots have been making great strides in the final frontier. From the MER rovers, now in their seventh year of exploring the surface of Mars, to the Huygens probe on Saturn's moon Titan, to the Voyager spacecraft traveling to the farthest reaches of our solar system and, perhaps one day, the nearest stars, it seems that machines have us beat when it comes to exploring space.

Robots can get their energy from nuclear batteries or solar panels rather than food. They don't need sleep or water or oxygen, and the long-term effect of radiation is not as destructive as it is for humans. Setting aside the example of HAL 9000 in Arthur C. Clarke's story *2001: A Space Odyssey*, computers are more psychologically suited than humans to spend eternity alone in the cosmos.

NASA has several projects underway to develop better “[human-machine interfaces](#).” The goal of this research is to improve communication between people and computers, making the machines our “avatars” for space exploration.

Hughes thinks there will come a day when this kind of research will allow us to manipulate robots and other machines as easily and naturally as we move our own body.

“I imagine that as soon as we have this kind of direct control over our various kinds of machines, our way of perceiving ourselves will change, just like we currently see our cell phones and cars as extensions of ourselves,” says Hughes.

Perhaps a brain implant linking us to our robots would be the next step in space exploration, greatly reducing communication time across the vast expanse of space. For instance, depending on where Mars is in its orbit, it takes between 3 to 30 minutes for a radio message sent from Earth to reach Mars, and then an equally long time for us to get the response. For more distant destinations, the message relay would take even longer. But if the theory of [quantum entanglement](#) somehow could be utilized, thought communication could be virtually instantaneous.

Warwick says that implanting computer chips in the brain to improve communication is a fairly straight-forward development, much as the telephone was the next step from the telegraph.

“The concept of a talking telegraph was considered crazy,” says Warwick. “I think there’s an element of that [when people consider communicating via brain implants], instead of seeing the scientific potential.”

One debate in the space community is whether humans or robots should be sent to explore. While there are compelling arguments for both sides, we must find a way to make extended human space travel feasible if we hope to survive when our Sun becomes a Red Giant star in about 5 billion years. When this happens, our planet and all life on it will be consumed. But perhaps by this point in the future, we may have become so merged with our machines that the “human versus robots” debate is moot.

In fact, that’s the conclusion reached by scientists involved in the search for extraterrestrial intelligence (SETI). Paul Davies, a SETI scientist at Arizona State University, says in his book *The Eerie Silence* that any aliens exploring the universe will be machine hybrids. Not only are machines better able to endure extended exposure to the conditions of space, but they have the potential to develop intelligence far beyond the capacity of the human brain.

“I think it very likely – in fact inevitable – that biological intelligence is only a transitory phenomenon, a fleeting phase in the evolution of the universe,” Davies writes. “If we ever encounter extraterrestrial intelligence, I believe it is overwhelmingly likely to be post-biological in nature.”

Hughes completely agrees that space travelers will likely be mechanical rather than organic. “If you’re looking out 200 years into the future of the colonization of space, humans are probably not going to be a factor,” he says.

The Human Element

Those who do not wish to become cyborgs (and who do not embrace our cyborg overlords) may become depressed by such conclusions.

One of the biggest concerns about our future as cyborgs comes out of our experience with computers. If all our brains are connected, what happens if a computer virus is introduced? How will we be able to maintain our privacy if a hacker can plug into our brain? Will there even be such a thing as an individual identity, or will we become like ants in a colony or bees in a hive?

Human-cyborg insect colonies may seem like science fiction, but cyborg insects are now being developed by the U.S. military’s Defense Advanced Research Projects Agency (DARPA). Their “HI-MEMS” project inserts a computer chip into an insect pupae, and the chip becomes connected to the body as the insect develops.

“Since a majority of the tissue development in insects occurs in the later stages of metamorphosis, the renewed tissue growth around the MEMS will tend to heal, and form a reliable and stable tissue-machine interface,” says the [HI-MEMS](#) website.

Electrical signals could directly stimulate muscles, cells or neurons, while ultrasonic pulses, pheromones,

and optical cues also could be used to control the insect's flight. In this way, DARPA hopes to create unobtrusive and cheaply-made cyborg spies.

According to the HI-MEMS website, "The intimate control of insects with embedded microsystems will enable insect cyborgs, which could carry one or more sensors, such as a microphone or a gas sensor, to relay back information gathered from the target destination."

While the program has created cyborg beetles and moths so far, it's not yet ready to release swarms of insect spies. DARPA also has funded research to develop cyborg sharks, where smells and electrical signals are used to steer the sharks in desired directions. Other experiments by various researchers to merge animals and machines have used pigeons, cats, and rats. Such experiments are staples of science fiction, from the cyborg dolphin in William Gibson's *Johnny Mnemonic* to the housefly monitors in Philip K. Dick's *Lies, Inc.*

For every dystopian tale of the potential evils of science, there are just as many hopes of how science could free us from a long list of medical maladies. The future of cyborg science likely will be a complicated mix of both good and bad outcomes. Warwick says that scientists, who are driven to investigate for the sheer joy of discovery, don't spend too much time worrying about the practical results of their research.

"I think it's important to be aware and to try to discuss the positive and negative sides," says Warwick. "But to be honest, you never know. With the RFID implant that I had, which was a relatively trivial thing, I found out that a nightclub in Barcelona uses it as a fashion item to attract people to come to the nightclub. You don't have to pay for your drinks; it's all charged to your implant. So there's always going to be something around the corner that you'd just never imagined."